November 15, 1860.

Major-General SABINE, R.A., Treasurer and Vice-President, in the Chair.

In accordance with the Statutes, notice was given from the Chair of the ensuing Anniversary Meeting for the election of Council and Officers.

David Forbes, Esq., was admitted into the Society.

The following communication was read:—

I. "On the Laws of the Phenomena of the larger Disturbances of the Magnetic Declination in the Kew Observatory: with notices of the progress of our knowledge regarding the Magnetic Storms." By Major-General Edward Sabine, R.A., Treas. and V.P. Received November 15, 1860.

The laws manifested by the mean effects of the larger magnetic disturbances (regarded commonly as effects of magnetic storms) have been investigated at several stations on the globe, being chiefly those of the British Colonial Observatories; but hitherto there has been no similar examination of the phenomena in the British Islands themselves. The object of the present paper is to supply this deficiency, as far as one element, namely the declination, is concerned, by a first approximation derived from the photographs in the years 1858 and 1859, of the self-recording declinometer of the observatory of the British Association at Kew; leaving it to the photographs of subsequent years to confirm, rectify, or render more precise the results now obtained by a first approximation. The method of investigation is simple, and may be briefly described as follows:—

The photographs furnish a continuous record of the variations which take place in the direction of the declination-magnet, and admit of exact measurement in the two relations of time, and of the amount of departure from a zero line. From this automatic record, the direction of the magnet is measured at twenty-four equal intervals of time in every solar day, which thus become the equivalents of the "hourly observations" of the magnetometers in use at the Colonial Observatories. These measures, or hourly directions of the magnet, are entered in monthly tables, having the days of the month

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in successive horizontal lines, and the hours of the day in vertical columns. The "means" of the entries in each vertical column indicate the mean direction of the magnet at the different hours of the month to which the table belongs, and have received the name of "First Normals." On inspecting any such monthly table, it is at once seen that a considerable portion of the entries in the several columns differ considerably from their respective means or first normals, and must be regarded as "disturbed observations." The laws of their relative frequency, and amount of disturbance, in different years, months and hours, are then sought out, by separating for that purpose a sufficient body of the most disturbed observations, computing the amount of departure in each case from the normal of the same month and hour, and arranging the amounts in annual, monthly, and hourly tables. In making these computations, the first normals require to be themselves corrected, by the omission in each vertical column of the entries noted as disturbed, and by taking fresh means, representing the normals of each month and hour after this omission, and therefore uninfluenced by the larger disturbances. These new means have received the name of "Final Normals," and may be defined as being the mean directions of the magnet in every month and every hour, after the omission from the record of every entry which differed from the mean a certain amount either in excess or in defect.

In this process there is nothing indefinite; and nothing arbitrary save the assignment of the particular amount of difference from the normal which shall be held to constitute the measure of a large disturbance, and which, for distinction sake, we may call "*the separating value*." It must be an amount which will separate a sufficient body of disturbed observations to permit their laws to be satisfactorily ascertained; but in other respects its precise value is of minor significancy; and the limits within which a selection may be made, without materially affecting the results, are usually by no means narrow; for it has been found experimentally on several occasions, that the *Ratios* by which the periodical variations of disturbance in different years, months and hours are characterized and expressed, do not undergo any material change by even considerable differences in the amount of the separating value. The separating value must necessarily be larger at some stations than at others, because the absolute magnitude of the disturbance-variation itself is very different in different parts of the globe, as well as its comparative magnitude in relation to the more regular solar-diurnal variation; but it must be a *constant* quantity throughout at one and the same station, or it will not truly show the relative proportion of disturbance in different years and different months.

The strength of the Kew establishment being insufficient for the complete work of a magnetic observatory, the tabulation of the hourly directions from the photographic records has been performed by the non-commissioned officers of the Royal Artillery, employed under my direction at Woolwich, where this work has been superintended by Mr. John Magrath, the principal clerk, as have been also the several reductions and calculations, which have been made on the same plan as those of the Colonial Observatories.

In the scale on which the changes of direction of the declination-magnet are recorded in the Kew photographs, one inch of space is equivalent to 22′·04 of arc. On a general view and consideration of the photographs during 1858 and 1859, 0·15 inch, or 3′·31 of arc appeared to be a suitable amount for the separating value to be adopted at that station; consequently every tabulated value which differed 3′·31 or more, either in excess or defect from the final normal of the same month and hour, has been regarded as one of the larger disturbances, and separated accordingly. The number of disturbed observations in the two years was 2424 (viz. 1211 in 1858, and 1213 in 1859), being between one-seventh and one-eighth of the whole body of hourly directions tabulated from the photographs, of which the number was 17,319. The aggregate valne of disturbance in the 2424 observations, was 14,901 minutes of arc; of which 7207 minutes were deflections of the north end of the magnet to the west, and 7694 to the east; the easterly deflections thus having a slight preponderance. The number of the disturbed observations, as well as their aggregate values, approximated very closely in each of the two years, 1859 being very slightly in excess. The *decennial period* of the magnetic storms, indicated by the observations at the British Colonial Observatories between 1840 and 1850, had led to the anticipation that the next epoch of maximum of the cycle might take place in the years 1858–1859. The nearly equal proportions in which the numbers and aggregate values of the larger disturbances took place in 1858 and 1859 are so far in accordance with this view. Should the records of the succeeding years at Kew, made with the same instruments, and examined by the same method, show decreasing disturbance in 1860 and 1861, the precise epoch of the maximum indicated by the records of the Kew declinometer will be "the end of 1858 or commencement of 1859."

In Table I. are shown the aggregate values of disturbance in the two years, arranged under the several hours of solar time in which they occurred. They are also divided into the two categories of westerly and easterly deflections, since the experience gained at other stations has now fully established that the westerly and easterly disturbance-deflections are characterized in all parts of the globe by distinct and dissimilar laws. The Ratios are also shown which the aggregate values at the different hours, both of the westerly and the easterly deflections, bear to their respective mean values,—or, in other words, to the sums respectively of the westerly and easterly deflections at all the hours, divided by 24, and taken as the respective units.

TABLE I.—Showing the aggregate values of the larger disturbances of the Declination at the different hours of solar time in 1858 and 1859, derived from the Kew Photographs; with the Ratios of disturbance at the several hours to the mean hourly value taken as the Unit.

Mean astronomical hours.	Westerly deflections.		Easterly deflections.		Mean civil hours.
	Aggregate values. (Minutes of arc.)	Ratios.	Aggregate values. (Minutes of arc.)	Ratios.	
18	553·9	1·85	118·9	0·37	6 A.M.
19	549·3	1·83	120·9	0·38	7 A.M.
20	442·9	1·48	115·2	0·36	8 A.M.
21	370·1	1·23	121·2	0·38	9 A.M.
22	376·9	1·26	104·6	0·33	10 A.M.
23	361·8	1·21	125·8	0·39	11 A.M.
0	413·7	1·38	173·0	0·54	Noon.
1	431·1	1·44	153·3	0·48	1 P.M.
2	459·8	1·53	173·0	0·54	2 P.M.
3	513·0	1·71	108·4	0·34	3 P.M.
4	403·9	1·35	141·0	0·44	4 P.M.
5	343·8	1·15	164·8	0·51	5 P.M.
6	282·5	0·94	291·1	0·91	6 P.M.
7	110·7	0·37	381·8	1·19	7 P.M.
8	65·6	0·22	499·0	1·56	8 P.M.
9	88·2	0·29	572·9	1·79	9 P.M.
10	59·0	0·20	724·3	2·25	10 P.M.
11	35·7	0·12	767·8	2·38	11 P.M.
12	146·7	0·49	709·5	2·21	Midnight.
13	141·8	0·47	634·8	1·98	1 A.M.
14	146·7	0·49	577·2	1·80	2 A.M.
15	151·5	0·51	464·8	1·45	3 A.M.
16	289·5	0·97	305·8	0·95	4 A.M.
17	458·9	1·53	144·9	0·45	5 A.M.
Mean hourly value 299·9 = 1·00			Mean hourly value 320·6 = 1·00		

The westerly and easterly deflections in the British Islands, as represented by the automatic records at Kew, are obviously governed, as in all other parts of the globe where the phenomena have been analysed, by distinct laws. The westerly deflections have their chief prevalence from 5 A.M. to 5 P.M., or during the hours of the *day*; the easterly deflections, on the other hand, prevail chiefly during the hours of the *night*, the ratios being above unity from 7 P.M. to 3 A.M., and below unity at all other hours. The easterly have one decided maximum, viz. at 11 P.M., towards which they steadily and continuously progress from 5 P.M., and from which they as steadily and continuously recede until 5 A.M. the following morning. The westerly deflections appear to have two epochs of maximum, one from 6 to 7 A.M., the other about 3 P.M., progressing regularly towards the first named from 3 A.M., and receding from it to 9 A.M.; at 9, 10, and 11 A.M. the ratios remain almost sensibly the same, but towards noon they begin to increase afresh, and continue to do so progressively to the second maximum at 3 P.M., from which hour they progressively decrease to 7 P.M. Those ratios which are less than unity, viz. those of the westerly deflections from 6 P.M. to 4 A.M., and of the easterly from 4 A.M. to 6 P.M., do not in either case exhibit the same decided tendency to one or two well-marked minima, as the ratios which are above unity do in both cases towards their maxima. It is possible, however, that this may in some degree be explained by the following consideration:—

The aggregate values of the disturbances prevailing at the different hours, as stated in the Table, are those which have prevailed, not only over the forces which would retain the magnet in its *mean* position, but also over any disturbing influences in an opposite direction, which may be conceived to have existed contemporaneously; and we cannot but suppose that as both westerly and easterly disturbances do record themselves as prevailing at the same hours on different days, that these opposite influences may sometimes *coexist*, neutralizing each other and not appearing in the record. We may reasonably suppose that the degree in which the aggregate values in the Table, both westerly and easterly, may be diminished thereby at the different hours, may be in some measure indicated by the disparity, or the reverse, in the amount of the aggregate values of disturbance in the opposite directions at those hours. Thus we may suppose that at a particular hour, 11 P.M. for example, when the amount of westerly deflections is very small, and of easterly very great, the diminution of the aggregate values of either by mutual counterbalance may be extremely small, while of equal absolute amount in both. Now a very small amount deducted from the large aggregate easterly value will scarcely have any effect whatsoever on the ratio at that hour to its unit or mean hourly value; whereas the same small amount deducted from the far less aggregate westerly value at the same hour would have a far more sensible effect upon its ratio. Assuming, therefore, the probability that westerly and easterly disturbing influences do sometimes coexist and neutralize each other in the record, and that we may in some degree judge of the respective amounts of the conflicting influences at the several hours by the means above stated, we should be prepared to expect that the ratios which are below unity do not represent the actual variations of the disturbing influences at those hours quite so purely as do the ratios which are above unity; and that they are liable to be affected, though in a very subordinate degree, by the abstraction of the neutralized portion, when the aggregate values which they represent are very small.

Without, however, resting undue weight upon this suggestion, we may safely say that the hours, when the ratios are below unity, are hours of comparative tranquillity, and that their variations from hour to hour are of a far less marked character than during the hours when the ratios exceed unity. Thus viewed, the character of the disturbance-diurnal variations may be conceived to have some analogy with that of the phenomena of the regular solar-diurnal variation. We may imagine the disturbance-variation (either the westerly or the easterly, it is indifferent which is taken),—divided as it is into two portions, by the ratios being in the one case above, and in the other below unity,—to correspond in one of its divisions to the hours when the sun is above the horizon, in the part of the hemisphere where the disturbance may be imagined to originate, whilst the other division, or that in which the ratios are below unity, and manifest hours of comparative tranquillity, may be viewed as the hours of night at the same locality. The solar hours at a station of observation which are characterized by disturbance ratios above unity, will in such case correspond in absolute time with the hours of the *day* at the supposed originating locality, modified (it may be) by a more or less rapid transmission of the disturbance. It will be understood, that in this hypothetical suggestion, the purpose in view is to aid the imagination, if it may be so, in apprehending the *ensemble* of the phenomena as far as they are yet known to us, rather than to advance a theoretical explanation, when we have not yet sufficient facts before us by which it may be judged; it may be remarked, however, that the conception of a double locality of origination of the disturbances (easterly and westerly) in the one hemisphere will present no especial difficulty to those who are conversant with the general facts of terrestrial magnetism.

If our attention be limited to the consideration of the facts observed at a single station, unaccompanied by a view of corresponding phenomena elsewhere, we might be in danger of regarding some of the features, particularly perhaps those which are not the most prominent, as having an accidental rather than a systematic origin; and we might thus lose a portion of the instruction which they may otherwise convey. On this account it has appeared desirable to exhibit the phenomena as observed at a second station, in comparison with those at Kew; and I have selected for this purpose the results of a similar investigation to the present at Hobarton in Tasmania; not only because the facts have been remarkably well determined there, but also because, though it is a very distant station, differing widely in geographical latitude and longitude, and situated indeed in a different hemisphere, there is a striking resemblance in the laws of the magnetic storms experienced at both. This resemblance, which is not only general, but extends to very minute particulars, is such that it seems impossible to resist the impression that the accordance cannot be accidental; and that the methods of observation and of analysis which have been pursued, have proved themselves well adapted to open to us the knowledge of the existence of systematic laws, pervading and regulating the action of the forces which are in daily operation around us, and are *at least* co-extensive with the limits of our globe; and thus to lead us ultimately to the correct theory of these forces. I have placed therefore beside each other in the next Table the Ratios of Disturbance at the different hours of local solar time at each of the two stations, separating them as before into westerly and easterly deflections, and placing the westerly deflections at Kew in immediate juxtaposition with the easterly at Hobarton, and *vice versâ*, as that obviously constitutes the just comparison. The Hobarton Ratios exhibit the relative prevalence of disturbance at the several hours, derived from hourly observations continued for seven years and nine months, viz. from January 1, 1841 to September 30, 1848; a series unparalleled in duration at any other of the Colonial Observatories, and which has borne admirably, as I shall hope to have a future opportunity of explaining to the Society, an unquestionable test of its substantial accuracy and fidelity. The number of recorded hourly observations was 56,202, of which 7638 differed from their respective normals of the same month and hour by an amount equalling or exceeding 2′·13 of arc, and constituted the body of separated observations from which the aggregate values of disturbance at the different hours and their ratios have been obtained. The proportion of disturbed observations thus separated, to the whole body of observations, is about 1 in 7·35; differing very little from the proportion already noticed as obtained at Kew by a separating value of 3′·3. The disturbing effects due to magnetic storms are therefore somewhat greater at Kew than at Hobarton, though some portion of the difference may be ascribed to the circumstance, that the terrestrial horizontal force, antagonistic to the disturbing forces and tending to retain the magnet in its mean position, is less at Kew than at Hobarton, in the proportion, approximately, of 3·7 to 4·5.

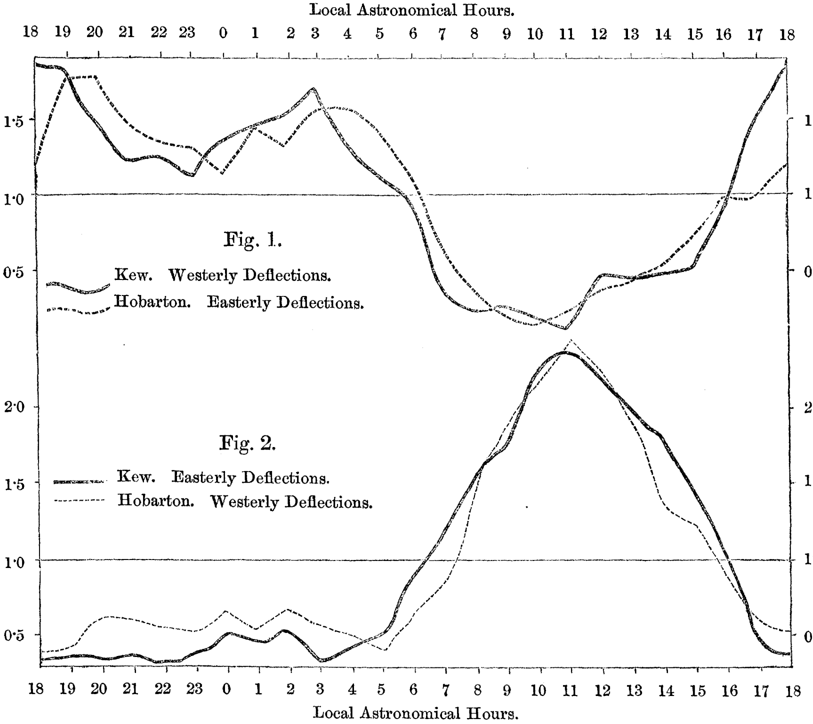
Table II.—Showing the comparison of the Ratios of the larger Disturbances of the Declination at the different hours of local solar time at Kew and Hobarton.

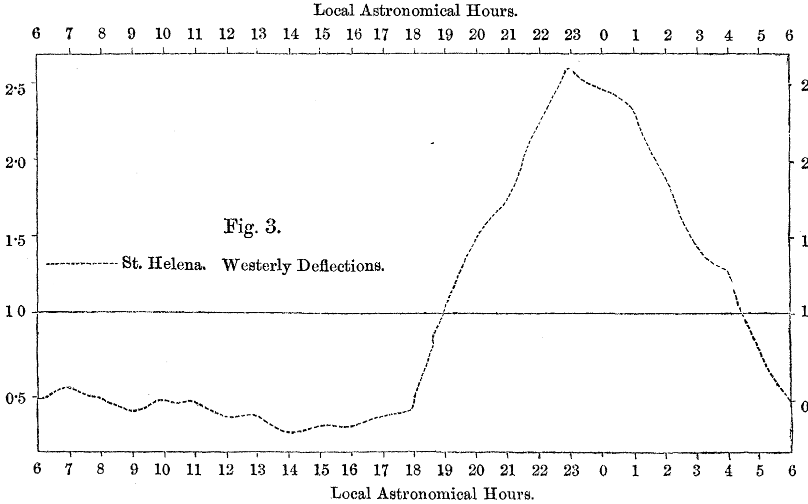
Local astronomical hours.	Kew. Westerly deflection.	Hobarton. Easterly deflection.	Kew. Easterly deflection.	Hobarton. Westerly deflection.	Local civil hours.
18	1·85	1·18	0·37	0·42	6 A.M.
19	1·83	1·75	0·38	0·44	7 A.M.
20	1·48	1·76	0·36	0·62	8 A.M.
21	1·23	1·47	0·38	0·60	9 A.M.
22	1·26	1·38	0·33	0·54	10 A.M.
23	1·21	1·31	0·39	0·53	11 A.M.
0	1·38	1·17	0·54	0·67	Noon.
1	1·44	1·44	0·48	0·56	1 P.M.
2	1·53	1·31	0·54	0·68	2 P.M.
3	1·71	1·56	0·34	0·60	3 P.M.
4	1·35	1·58	0·44	0·50	4 P.M.
5	1·15	1·41	0·51	0·42	5 P.M.
6	0·94	1·10	0·91	0·68	6 P.M.
7	0·37	0·62	1·19	0·90	7 P.M.
8	0·22	0·37	1·56	1·50	8 P.M.
9	0·29	0·22	1·79	1·87	9 P.M.
10	0·20	0·17	2·25	2·20	10 P.M.
11	0·12	0·22	2·38	2·43	11 P.M.
12	0·49	0·38	2·21	2·15	Mid.
13	0·47	0·41	1·98	1·74	1 A.M.
14	0·49	0·53	1·80	1·35	2 A.M.
15	0·51	0·71	1·45	1·25	3 A.M.
16	0·97	1·01	0·95	0·85	4 A.M.
17	1·53	0·96	0·45	0·48	5 A.M.

For the convenience of those who prefer graphical illustration, I have represented on an accompanying woodcut the results to which I have referred. The curves drawn in unbroken black lines, in figures 1 and 2, show the phenomena at Kew; those in dotted lines in the same figures, the phenomena at Hobarton. Fig. 1 presents westerly disturbances at Kew, and easterly at Hobarton in comparison with each other; they are obviously allied phenomena. Fig. 2 presents easterly disturbances at Kew and westerly at Hobarton; these are also, obviously, allied phenomena, but are as obviously governed by distinct laws from those in fig. 1.

Had the phenomena at Kew and Hobarton been the only ones known to us, we might have inferred that we had obtained the characteristic forms of the diurnal variations due to the action of two distinct and independent forces; and we might have expected with some degree of confidence to have found curves of corresponding

Mean Diurnal Disturbance Variation of the Magnetic Declination.
Figs. 1 *and* 2, *Kew and Hobarton. Fig.* 3, *St. Helena.*





form by a similar analysis elsewhere;—and so far experience has been in accord with expectation. But, as the *forms* of these two pair of curves are not only respectively similar, but as they also correspond in the *hours* at which their chief characteristic features occur, we might also have formed an inference which would have proved erroneous, viz. that the hours as well as the forms would be the same at other stations. Now this is so far from being in accordance with the facts which we already possess, that whilst the forms present generally a marked resemblance, the hours at different stations exhibit every variety. To exemplify this I have given in a third figure the curve of the westerly disturbance-diurnal variation at St. Helena, of which the form is manifestly the same as that of the two curves in fig. 2, whilst the hours of its most marked features exhibit a difference of nearly 12 hours of local time from those in fig. 2.

It may not be unsuitable on the present occasion to take a brief retrospective view of the progress of our knowledge respecting these remarkable phenomena, videlicet, the *casual magnetic disturbances*, or *magnetic storms*. Antecedently to the formation of the German Magnetic Association and the publication of its first Annual Report in 1837, our information concerning them went no further than that there occurred at times, apparently not of regular recurrence, extraordinary agitations or perturbations of the magnetic needle, which had been noticed in several instances to have taken place *contemporaneously* in parts of the European continent distant from each other; and to have been accompanied by remarkable displays of Aurora, seen either at the locality itself where the needle was disturbed, or observed contemporaneously elsewhere. The opinion which appears to have generally prevailed at this time, was that the Aurora and the magnetic disturbances were kindred phenomena, originating probably in atmospherical derangements, or connected at least in some way with disturbances of the atmospherical equilibrium. They were classed accordingly as "Meteorological Phenomena," and were supposed to have a local, though it might be in some instances a wide, extension and prevalence.

The special purpose of the German Magnetic Association was to subject the "*irregular magnetic disturbances*" (as they were then called in contradistinction to the regular periodical and secular variations) to a more close examination, by means of systematized observations made simultaneously in many parts of Germany. With this view, six concerted days in each year were set apart in which the direction of the declination-magnet should be observed with great accuracy, by methods then for the first time introduced, at successive intervals of five minutes for twenty-four consecutive hours; the meteorological instruments being observed at the same time. The clocks at all the stations were set to Göttingen mean time (Göttingen being the birth-place of the Association), and the observations were thus rendered strictly simultaneous throughout. The high respect entertained for the eminent persons with whom the scheme of the Association originated, obtained for it a very extensive cooperation, not limited to Germany alone, but extending over a great part of the European Continent. The observations of the "Term-days," as they were called, were maintained until 1841, and were all transmitted to Göttingen for coordination and comparison.

The principal results of this great and admirably conducted cooperative undertaking were published in works well known to magneticians. They may be summed up as follows:—The phenomena which were the subjects of investigation were shown to be of casual and not regular occurrence; to prevail contemporaneously everywhere within the limits comprehended by the observations; and to exhibit a correspondence surprisingly great, not only in the larger, but even in almost all the smaller oscillations; so that, in the words of the Reporters, MM. Gauss and Weber, "nothing in fact remained which could justly be ascribed to *local* causes."

Equally decided were the conclusions drawn against the previously imagined connexion between the magnetic disturbances and derangements of the atmosphere, or particular states of the weather. No perceptible influence whatsoever on the needle appeared to be produced either by wind-storms or by thunder-storms, even when close at hand.

The correspondence in the simultaneous movements of the declination-magnet, so strikingly manifested over an area of such wide extent, was however more remarkable in respect to the *direction* of a perturbation than to its *amount*. The disturbances at different stations, and even, as was expressly stated, at *all* the stations, coincided, even in the smaller instances, in time and in direction, but *with dissimilar proportions of magnitude.* Thus it was found generally that by far the greater number of the anomalous indications were smaller at the southern stations and larger at the northern; the difference being greater than would be due to the difference in the antagonistic retaining force (*i. e.* the horizontal force of the earth's magnetism, which is greater at the southern than at the northern stations). The generality of this occurrence led to the unavoidable inference, that, in Europe, the energy of the disturbing force must be regarded weaker as we follow its action towards the south.

A close and minute comparison of the simultaneous movements at stations in near proximity to each other led to the further conclusion, also stated to be unavoidable, that "various forces must be admitted to be contemporaneously in action, being probably quite independent of each other, and having very different sources; the effects of these various forces being intermixed in very dissimilar proportions at various places of observation according to the directions and distances of these from the sources whence the perturbations proceed." (Resultate aus den Beob. des Mag. Vereins, 1836. pp. 99, 100.) The difficulty of disentangling the complications which thus occur at every individual station was fully foreseen and recognized; and the Report, which bears the initial of M. Gauss, concludes with the remark that "it will be a triumph of science, if at some future time we should succeed in reducing into order the manifold intricacies of the combinations, in separating from each other the several forces of which they are the compound results, and in assigning the source and measure of each."

Such was the state of the inquiry when it was entered upon by the Royal Society. The Report of the Committee of Physics drawn up (*inter alia*) for the guidance of the Magnetic Observatories established by H.M. Government for a limited period in four of the British Colonies, bears date in 1840. The objects proposed by this Report were a very considerable enlargement upon those of the German Association, as well as an extension of the research to more distant parts of the globe. The German observations had been limited for the most part to one only of the three elements required in a complete investigation. When the German Association commenced its operations, the Declination was the sole element for which an apparatus had been devised capable of recording its variations with the necessary precision. To meet the deficiency in respect to the horizontal component of the magnetic force, M. Gauss constructed in 1837 his bifilar magnetometer, which was employed at Göttingen and at some few of the German stations, concurrently with the Declinometer, in the term observations of the concluding years of the Association. But an apparatus for the corresponding observation of the vertical portion of the Force was as yet wholly wanting; without such an apparatus as a companion to the bifilar, no determination could be made of the perturbations or momentary changes of the magnetic Dip and Force: and without a knowledge of these no satisfactory conclusion in regard to the real nature, amount and direction of the perturbing forces could be expected. The ingenuity of Dr. Lloyd supplied the desideratum by devising the vertical force magnetometer, which, with adequate care, has been found scarcely, if at all, inferior to the bifilar in the performance of its work. The scheme of the British Observatories was thus enabled to comprehend all the data required for the investigation of the casual disturbances, whether that investigation was to be pursued as before by concerted simultaneous observations at different stations, or, as suggested in the Report, *by the determination of the laws, relations and dependencies of the disturbances at individual stations obtained independently and without concert with other observers or other stations.* Thus, in reference to these particular phenomena, the British system was both an enlargement and an extension of the objects of the German Association; but it also embraced within its scope the determinations with a precision, not previously attempted, of the *absolute values* of the three elements, and of *the periodical and progressive changes* to which they are subject; premising however, and insisting with a sagacity which has been fully justified by subsequent experience, on the necessity of eliminating in the first instance the effects of the casual and transitory variations, as an indispensable preliminary to a correct knowledge and analysis of the progressive and periodical changes. A further prominency was given to investigations into the particular class of phenomena which form the subject of this paper, by the declaration that "the theory of the transitory changes is in itself one of the most interesting and important points to which the attention of magnetic inquirers can be turned, as they are no doubt intimately connected with the general causes of terrestrial magnetism, and will probably lead us to a much more perfect knowledge of these causes than we now possess."

The instructions contained in the Royal Society's Report for the adjustments and manipulation of the several instruments provided for these purposes were clear, simple and precise. In looking back upon them after the completion of the services for which they were designed, it is impossible to speak of the instructions otherwise than with unqualified praise. But the guidance afforded by the instructions terminated with the completion of the observations. To have attempted to prescribe the methods by which conclusions, the nature of which could not be anticipated, should be sought out from observations not yet made, would have been obviously premature. Yet without some discussion of the results, the mere publication of unreduced observations is comparatively valueless. It has been well remarked by an eminent authority, whose opinions expressed in the Royal Society's Report have been frequently referred to in the course of this paper, that "a man may as well keep a register of his dreams, as of the weather, or *any other set of daily phenomena*, if the spirit of grouping, combining, and eliciting results be absent." It was indispensable that the attempt should be made to gather in at least the first fruits of an undertaking on which a considerable amount of public money and of individual labour had been expended; and the duty of making the attempt might naturally be considered to rest on the person who had been entrusted with the superintendence of the Government Observatories. The methods and processes adopted for reducing, combining, eliminating, and otherwise eliciting results were necessarily of a novel description; they were in fact an endeavour to find a way by untrodden paths to simple and general phenomenal laws where no definite knowledge of the origin or mode of causation of the phenomena previously existed. Happily it is not necessary to trespass on the time or attention of the Society by a description of the methods and processes which have been employed to elucidate some of the leading features of the magnetic storms, as these are fully described in the discussions prefixed to the ten large volumes in which the observations at the Colonial Observatories have been printed. It will be only necessary to advert, and that very briefly, to some of the principal conclusions which may be supposed to throw most light on the theory of these phenomena.

The results of the extension of the term-day comparisons to the

American Continent, and to the Southern Hemisphere and the Tropics, may first be disposed of in a very few words. The contemporaneous character of the disturbances, which had been shown by the German term-observations to extend over the larger portion of the European Continent, manifested itself also in the comparisons of the term-days in 1840, 1841, and 1842 at Prague and Breslau in Europe, and Toronto and Philadelphia in America, published in 1845; and the same conclusion was obtained by comparing with each other the term-days at the Colonial Observatories, situated in parts of the globe most distant from one another. The days of disturbance still appeared to be of casual occurrence, but were now recognized as affections common to the *whole globe*, showing themselves simultaneously at stations most widely removed from each other. When distant stations were compared, as for example stations in Europe with those in America, and either or both with Tasmania, discrepancies in the amount of particular perturbations, similar to those which had been found in comparing the European stations with each other, presented themselves, but larger and more frequent, and extending occasionally even to the *reversal* of the *direction* of the simultaneous disturbance. Instances were not unfrequent of the same element, or of different elements, being disturbed at the same observation-instant in Europe and America; and on the other hand, there were perturbations, sometimes of considerable magnitude, on the one continent, of which no trace was visible on the other. Hence it was concluded, with the increased confidence due to this additional and more extensive experience, that various forces proceeding from different sources were contemporaneously in action; and it was further inferred that the most suitable and promising mode of pursuing the investigation was by an endeavour to analyse the effects produced at individual stations, and to resolve them if possible into their respective constituents.

The hourly observations which had been commenced at the Colonial stations in 1841 and 1842, and continued through several subsequent years, furnished suitable materials for this investigation, the first fruits of which were the discovery, that the disturbances, though casual in the times of their occurrence, and most irregular when individual perturbations only were regarded, were, in their *mean* effects, *strictly periodical phenomena*; conforming in each element, and at each station, on a mean of many days, to a law dependent on the solar hour ; thus constituting a systematic mean diurnal variation distinct from the regular daily solar-diurnal variation, and admitting of being separated from it by proper processes of reduction. This conformity of the disturbances to a law depending on the solar hours was the first known circumstance which pointed to the sun as their primary cause, whilst at the same time a difference in the *mode* of causation of the regular- and of the disturbance-diurnal variations seemed to be indicated by the fact, that in the disturbance-variation the local hours of maximum and minimum were found to vary (apparently without limit) in different meridians, in contrast to the general uniformity of those hours in the previously and more generally recognized regular solar-diurnal variation.

This first reference of the magnetic storms to the sun as their primary cause, was soon followed by a far more striking presumptive evidence of the same, by a further discovery of the existence of a periodical variation in the frequency of occurrence, and amount of aggregate effects, of the magnetic storms, corresponding in period, and coincident in epochs of maximum and minimum, with the decennial variation in the frequency and amount of the spots on the sun's disk, derived by Schwabe from his own systematic observations commenced in 1826 and continued thenceforward. The decennial variation of the magnetic storms is based on the observations of the four widely distributed Colonial Observatories, and is concurred in by all. This remarkable correspondence between the magnetic storms and physical changes in the sun's photosphere, of such enormous magnitude as to be visible from the earth even by the unassisted eye, must be held to terminate altogether any hypothesis which would assign to the cause of the magnetic disturbances a local origin on the surface or in the atmosphere of our globe, or even in the terrestrial magnetism itself, and to refer them, as cosmical phenomena, to direct solar influence ; leaving for future solution the question of the *mode* in which that influence produces the effects which we believe we have thus traced to their source in the central body of our system*.

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* The existence of a decennial period of the magnetic storms was not, as some have supposed, a fortuitous discovery ; but a consequence of a process of examination early adopted and expressly devised, by the employment of a *constant* separating value, to make known any period of longer or shorter duration which might

We may regard as a step towards this solution the separation of the disturbances of the declination into two distinct forces acting in different directions and proceeding apparently from different foci; the phenomena of distinct (though in so many respects closely allied) variations exhibit the same peculiar features at all the stations to which the analysis has hitherto extended, and have been exemplified by the observations at Kew, as shown in the early part of this paper. A similar separation into two independent affections, each having its own distinct phenomenal laws, has followed from an analysis of the same description applied to the disturbances of the magnetic dip and force at the Colonial stations; thus placing in evidence, and tracing the approximate laws of the effects of six distinct forces (two in each element) contemporaneously in action in all parts of the globe, and pointing in no doubtful manner to the existence of two terrestrial foci or sources in each hemisphere from which the action of the forces emanating from the sun and communicated to the earth may be conceived to proceed. Such an ascription naturally suggests to those conversant with the facts of terrestrial magnetism the possibility that Halley's two terrestrial magnetic foci in each hemisphere may be either themselves the localities in question, or may be in some way intimately connected with them. The important observations which we owe to the zeal and devotion of Captain Maguire, R.N. and the Officers of H.M.S. 'Plover,' have made us acquainted with Point Barrow as a locality where the magnetic disturbances prevail with an energy far beyond ordinary experience, indicating the proximity of that station to the source or sources from which the action of the forces may proceed. Now Point Barrow is situated in a nearly intermediate position between what we believe to be the present localities of

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fall within the limits comprised by the observations. The period being decennial, and the epoch of minimum occurring at the end of 1843 or beginning of 1844, the epoch of maximum was necessarily waited for in order to ascertain the precise duration of the cycle. The maximum took place in 1848–1849, the observations in 1850 and 1851 showing that the aggregate value of the annual disturbances was again diminishing as it had been in 1842 and 1843. The process of determining the proportion of disturbance in different years is a somewhat laborious one, and requires time: but in March 1852, I was able to announce to the Royal Society the existence of a decennial variation, based on the concurrent testimony of the observations at Toronto and Hobarton; deeming it proper that so remarkable a fact should not be publicly stated until it had been thoroughly assured by independent observations at two very distant parts of the globe.

Halley's northern foci, and at no great distance from either: in such a situation the exposure to disturbing influences proceeding from both might well be supposed to be very great. The displays of Aurora at Point Barrow exceed also in numerical frequency any record received from any other part of the globe.

The further prosecution of this investigation appears to stand in need of some more systematic proceeding than would be supplied by the uncombined efforts of individual zeal. Observations similar to those of the Kew Observatory, made at a few stations in the middle latitudes of the hemisphere, distributed with some approach to symmetry in their longitudinal distances apart, would probably furnish data, which by their combination might serve to assign the localities from whence the disturbances are propagated—contribute still further to disentangle the complications of the forces which produce them,—and thus hasten the attainment of that "triumph of science" foreseen and foreshadowed by the great geometrician of the last age. Of such a nature was the scheme contemplated by the Joint Committee of the Royal Society and British Association, and submitted to H.M. Government in the hope of obtaining their aid in the execution of such part of it as fell within British dominion; and of thus "maintaining and perpetuating our national claim to the furtherance and perfecting of this magnificent department of physical inquiry." (Herschel in 'Quarterly Review,' September 1840, p. 277.) The scheme was no unreasonable one: probably eight or nine stations in the contour of the hemisphere might suffice; and of these we already possess the observations at Toronto; those at Kew are in progress; and self-recording instruments, similar to those at Kew, are now under verification at Kew preparatory to being employed on the Western or Pacific side of the United States Territory, at a point not far from the previously desired Station of Vancouver Island, for which a substitute is thus provided. This Observatory, as well as one at Key West on the southern coast of the United States, in which self-recording instruments are already at work, will be maintained under the authority and at the expense of the American Government, and both have been placed under the superintendence of the able and indefatigable director of the "Coast Survey," Dr. Alexander Dallas Bache. The Russian Observatory at Pekin, the trustworthy observations of which are already known to the Society, is understood to have recommenced its hourly observations, and stands only in need of an apparatus for the vertical force (which might be readily supplied from this country), to contribute its full complement to the required data. More than half the stations may therefore be regarded as already provided for, and there are other Russian observatories in the desired latitudes and longitudes which might be completed with instruments for a full participation.

It would be wrong to conclude these imperfect notices without recognizing how greatly the researches have been aided in their progress by the united and unfailing countenance and support of the Royal Society and of the British Association. The Kew Observatory owes its existence and maintenance to funds most liberally supplied from year to year by the British Association; and the cost of the self-recording magnetic instruments, of which the first instalment of the results has formed the early part of this paper, was supplied from funds at the disposal of the Council of the Royal Society. Magnetical science, rapidly as it is advancing, is even yet in its infancy; and it is in their early stages particularly that all branches of natural knowledge stand in need of the fostering aid of societies in which science is valued and cultivated for its own sake.

November 22, 1860.

Major-General SABINE, R.A., Treasurer and Vice-President, in the Chair.

John Thomas Quekett, Esq., was admitted into the Society.

In accordance with the Statutes, notice was given of the ensuing Anniversary Meeting, and the list of Council and Officers proposed for election was read as follows:—

President.—Sir Benjamin Collins Brodie, Bart., D.C.L.

Treasurer.—Major-General Edward Sabine, R.A., D.C.L.

Secretaries.—William Sharpey, M.D., LL.D.
George Gabriel Stokes, Esq., M.A., D.C.L.

Foreign Secretary.—William Hallows Miller, Esq., M.A.

Other Members of the Council.—John Couch Adams, Esq.; Sir